



DØ High Voltage System Tutorial

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Outline

- Hardware
- EPICS Support
 - ◆ HV Record
 - ◆ HV Alarms
- Operator GUI Programs
 - ◆ HV Utility Display
 - ◆ Global HV Display
 - ◆ HV Channel Display
- Diagnostic Guidelines
- Ref:
 - ◆ \\D0server4\projects\Online_Computing\Tutorials\HvTutorial.ppt

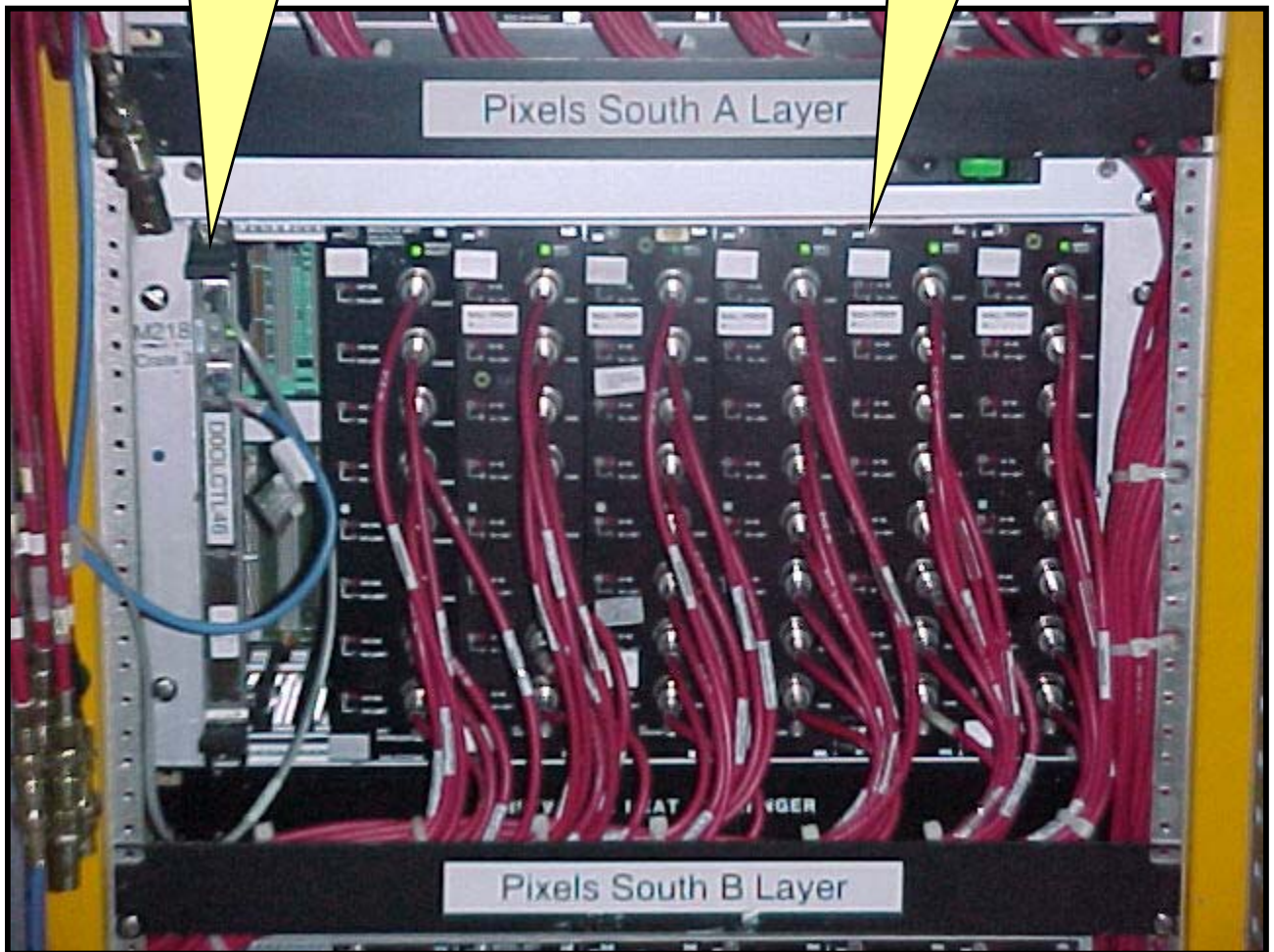


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Hardware - HV Crate

**MVME2301
IOC Processor**

**4877
Module**



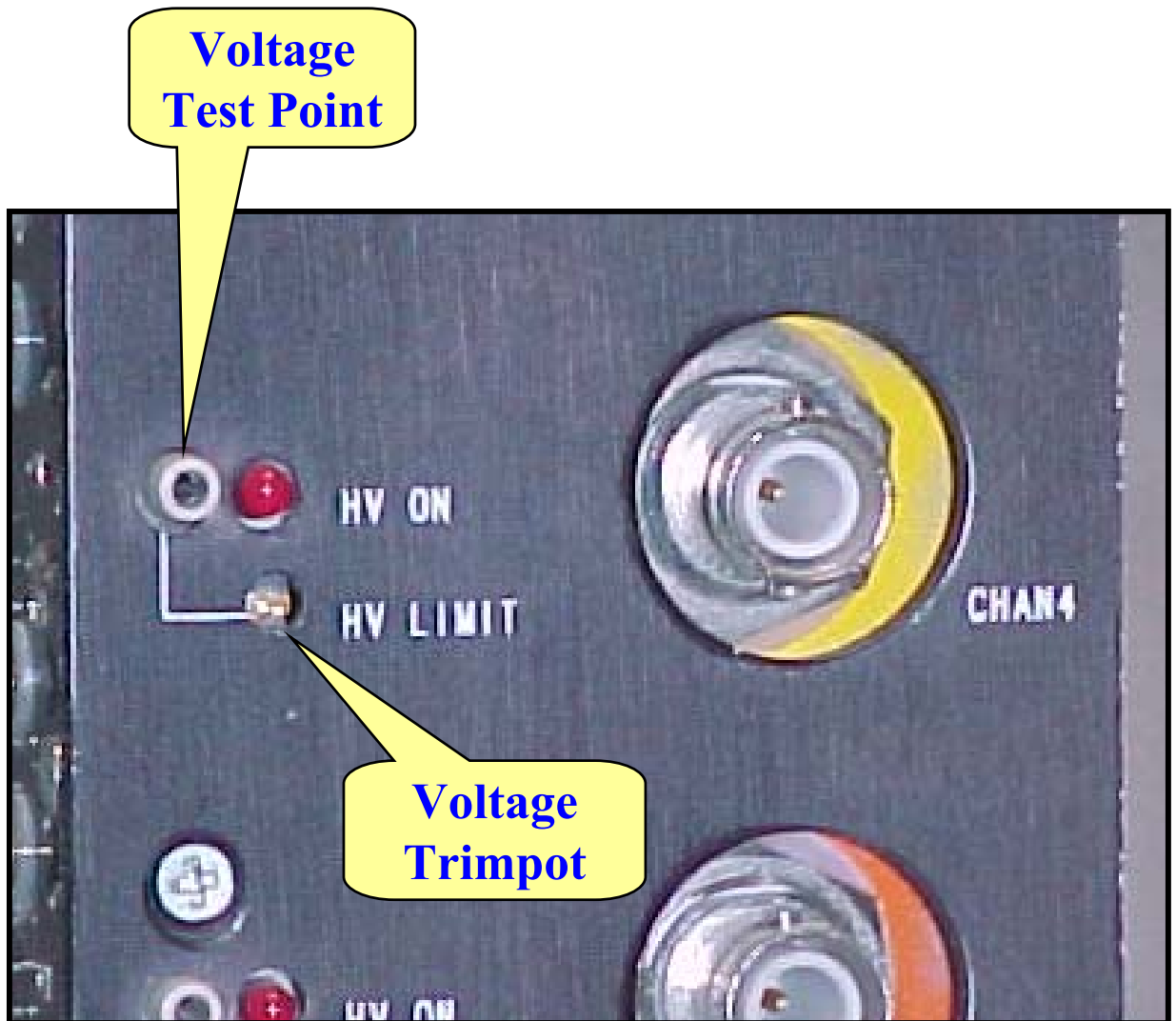
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Hardware - HV Module



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Hardware - HV Channel



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Hardware

- **VME crate**
 - ◆ 6U size
 - ◆ Custom backplane
 - ◆ Additional voltage supplies
 - +5V Digital, +- 12V Analog, +-12 V Bulk(Unfiltered)
- **Fermilab/BiRa 4877 module**
 - ◆ Cockroft-Walton generator
 - ◆ Six modules per VME crate
 - ◆ 8 channels per module
 - ◆ 10 voltage generator pod types
 - ◆ Backplane trip links
 - ◆ Backplane module address encoding (geographical)



Hardware

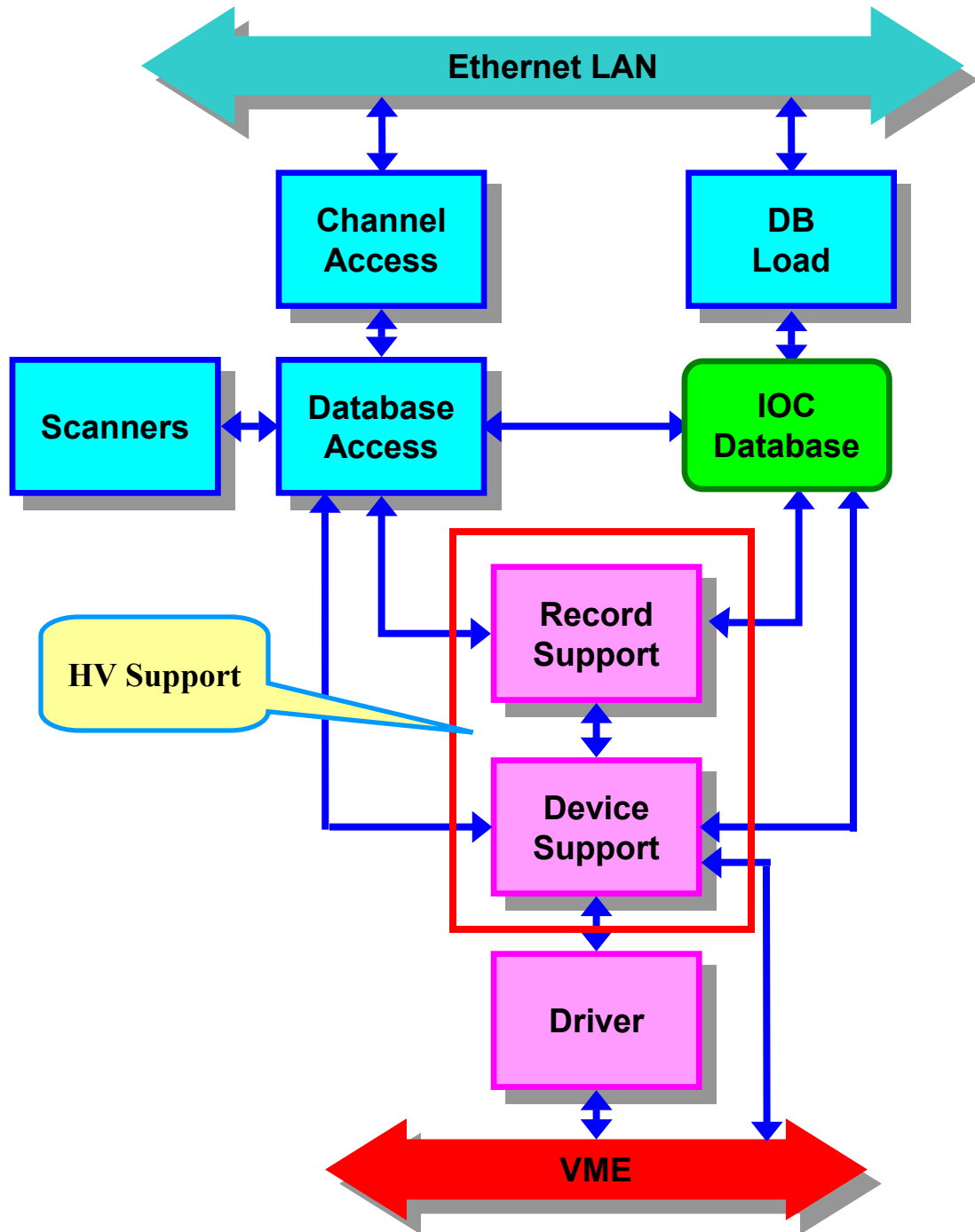
- **Reference**

- ◆ Bi Ra - “Model VME 4877PS
High Voltage Power Supply
System Manual”



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EPICS High Voltage Support



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HV Record

- HV Record - hv
 - ◆ High-level device interface
 - ◆ Sequential state machine model (limited implementation of Harel state diagram)
 - ◆ Ramp algorithm
 - Parabolic end sections
 - Linear center section
 - ◆ Convergence algorithm
 - Repeat ramp until within tolerance limit
 - Enter PAUSE state if repeat limit exceeded



HV Record

- **Purpose**
 - ◆ Control and monitor an individual HV channel
 - ◆ Add high-level operations to a basic voltage generator
- Implemented as a sequential state machine with states, transitions, actions, and events
- Ramping to a target voltage is a software function



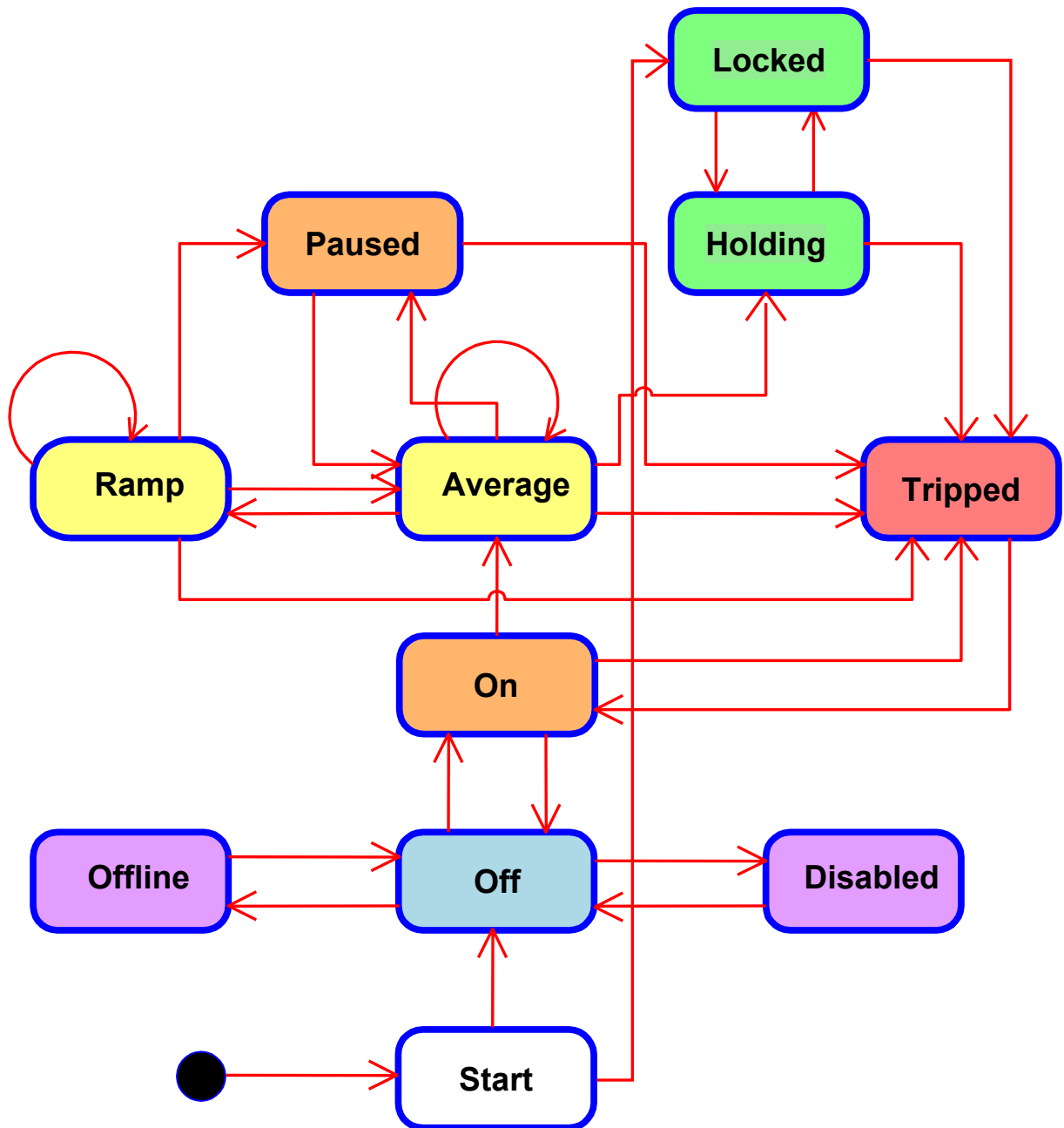
HV Record - Pod Types

Pod Name	Max Voltage	Max Current
P5.5KV1	+5.5kV	2.3 mA
M5.5KV1	-5.5 kV	2.3 mA
P5.5KV2	+5.5 kV	1.0 mA
M5.5KV2	-5.5 kV	1.0 mA
P5.5KV3	+5.5 kV	0.1 MA
M5.5KV3	-5.5 kV	0.1 mA
P3.5KV	+3.5 kV	3.5 mA
M3.5KV	-3.5kV	3.5 mA
P2.0KV	+2.0 kV	3.2 mA
M10V1	-10 V	0.2 mA



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HV Record - State Diagram



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HV Record - Ramp Algorithm

- Compute average voltage
- Compute voltage step size and number of steps to reach target voltage
- Execute ramp steps
- Compute average voltage
- Compare $\text{abs}(V_{\text{average}} - V_{\text{target}})$ with $V_{\text{tolerance}}$
 - ◆ less or equal - Enter HOLDING state
 - ◆ greater - Repeat ramp sequence



HV Record - Ramp Algorithm

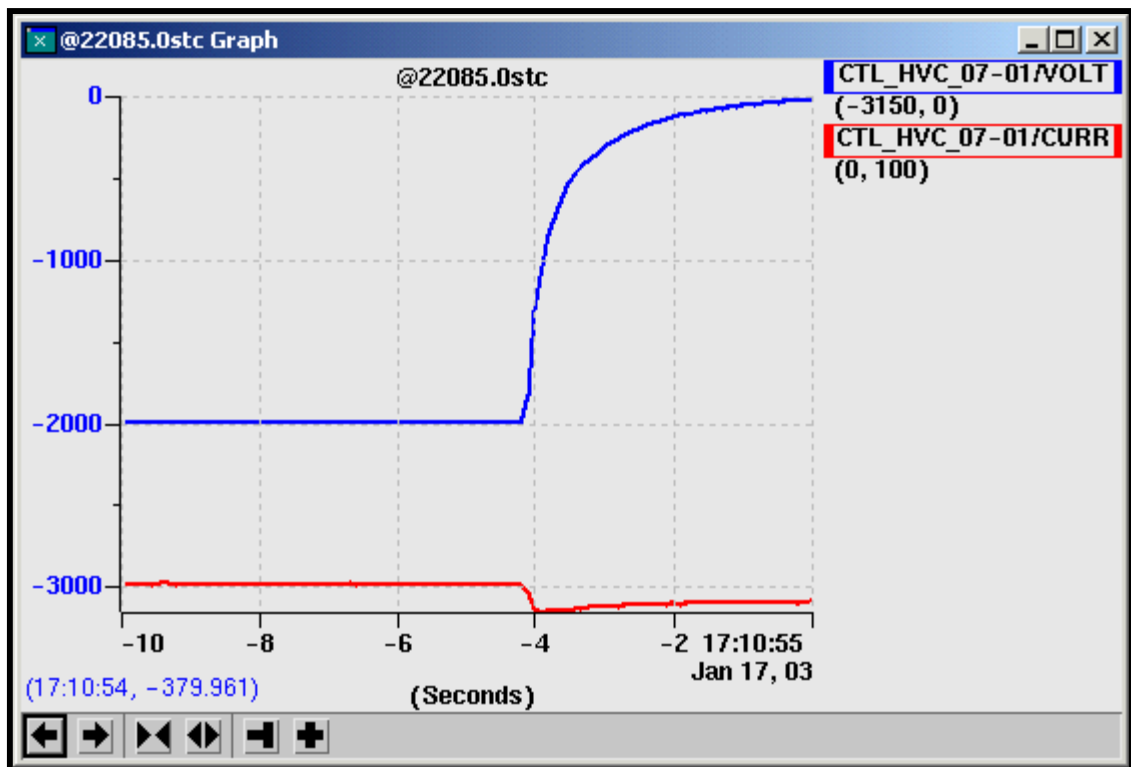
- If the number of ramp cycles exceeds the limit, enter the PAUSE state and set an alarm condition



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HV Record – Time Plots

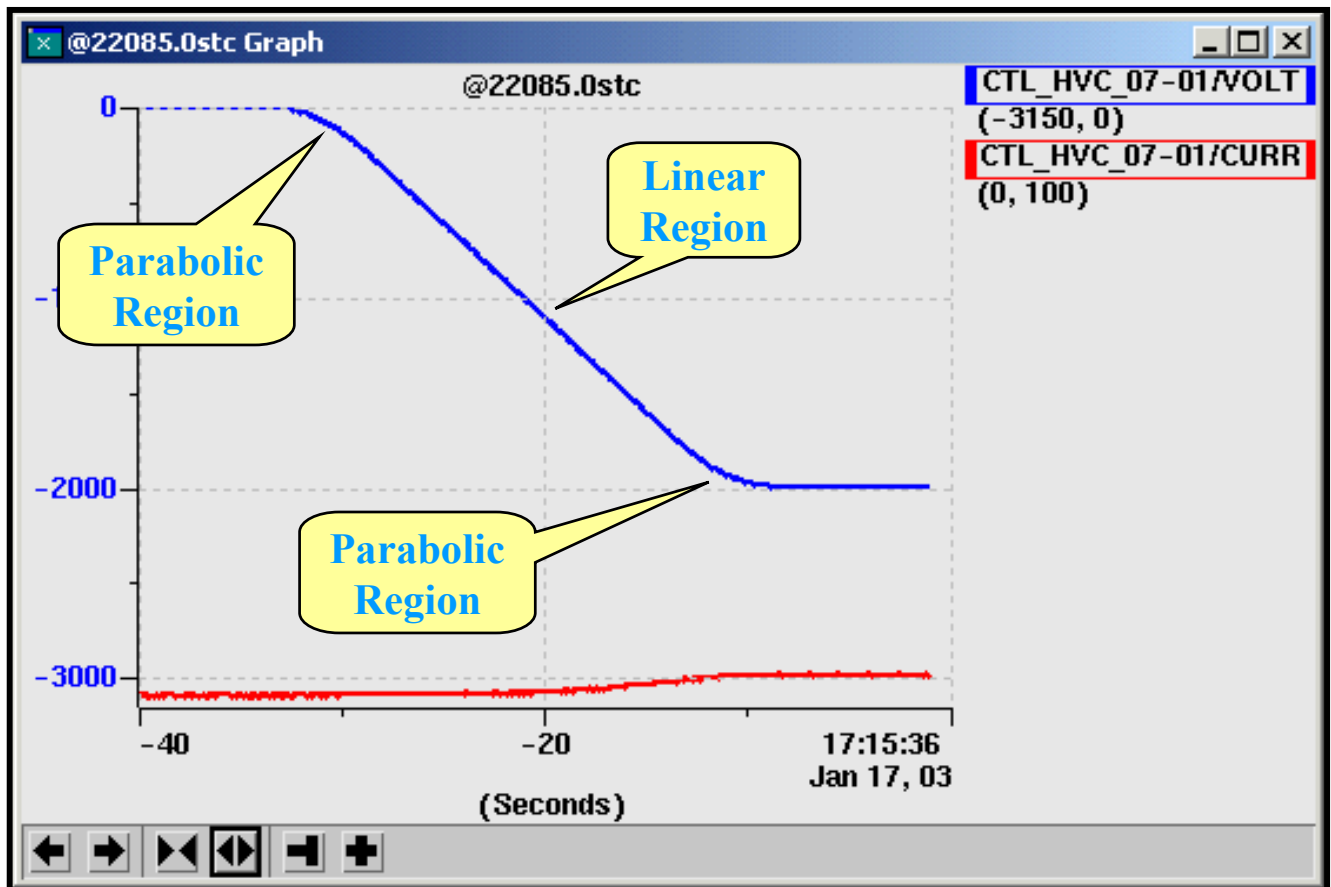
- Decay profile
 - ◆ Capacitive load



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HV Record – Time Plots

- Ramp regions
 - ◆ Parabolic ends
 - ◆ Linear center



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HV Record - Trips

- Channel

- ◆ Overvoltage

- Trimpot setting

- ◆ Overcurrent

- Register setting

- ◆ External

- Backplane connection

- Module

- ◆ Watchdog

- Access timeout (unused)

- ◆ Interlock

- Front panel connector (unused)

- ◆ External

- Backplane connection



HV Record - Parameters

- **ACCL**
 - ◆ Parabolic acceleration rate (Volts/Sec**2)
 - $\text{RATE/ACCL} = \text{Duration of parabolic region (Sec)}$
- **CSCAL**
 - ◆ Ramping current scaling factor
- **MAXC**
 - ◆ Current trip level (uAmps)
- **RATE**
 - ◆ Ramp rate (Volts/Sec)
- **VTOL**
 - ◆ Voltage setting tolerance



HV Alarms

- Invalid Alarm

- ◆ Hardware access error
- ◆ OFFLINE or INVALID state

- Minor Alarm

- ◆ OFF or PAUSED states
- ◆ Current warning limit exceeded
- ◆ Voltage warning limit exceeded

- Major Alarm

- ◆ TRIPPED state
- ◆ Current fatal limit exceeded
- ◆ Voltage fatal limit exceeded
- ◆ A tripped channel will pause the run



HV Alarms – SES Display

Voltage
Limit

State and
Current Limit

Alarm Display					
File View Settings Help					
Group Name	MAJOR	MINOR	INVALID	DISABLED	GOOD
Run Pause	0	562	0	0	0
HV	562	1686	0	0	0
MDT	0	0	1	0	0
PDT	0	1	0	0	2
SCINT	4	0	0	0	1
L1	0	0	0	0	0
PROC	0	4	0	0	0
All Muon	566	1691	1	1	3
Status: Connection to server started					



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Operator GUI Programs

- **HV Utility display**
 - ◆ Monitor crate parameters (backplane voltages and temperature)
- **Global HV display**
 - ◆ Monitor channel state for multiple crates
 - ◆ Control state change for multiple crates
- **HV Channel display**
 - ◆ Monitor channel parameters for a single crate
 - ◆ Control state change for single channel or all channels in a crate



HV Utility Display

Paging
Tabs

High Voltage Utility Display -						
File						Help
CAL	FPD	LUM	MUO	SMT		
Crate	+5 Digital	+12 Analog	-12 Analog	+12 Bulk	-12 Bulk	Temp DegC
Pixel						
M217C	5.04	12.31	-12.22	12.44	-12.66	19.32
M217D	5.10	12.23	-12.48	12.26	-12.45	20.22
M217E	5.09	12.21	-12.36	12.23	-12.10	21.33
M218C	5.28	12.14	-12.29	12.40	-12.34	22.89
M218D	5.17	12.17	-12.26	12.42	-12.29	25.60
M218E	5.10	12.28	-12.47	12.43	-12.26	21.39
Central						
M215B	5.04	12.26	-12.44	12.25	-12.56	21.67
M215C	5.01	12.36	-12.22	12.18	-12.27	20.61
M215D	5.04	12.30	-12.26	12.43	-12.61	19.65
M215E	5.09	12.22	-12.20	12.25	-12.33	21.73
M217B	5.02	12.28	-12.15	12.35	-12.30	21.93
M218B						
Status:						
Reconnect						



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HV Utility Display

- **Purpose**

- ◆ Monitor HV crate parameters
 - Backplane voltages
 - Temperature

- **Properties**

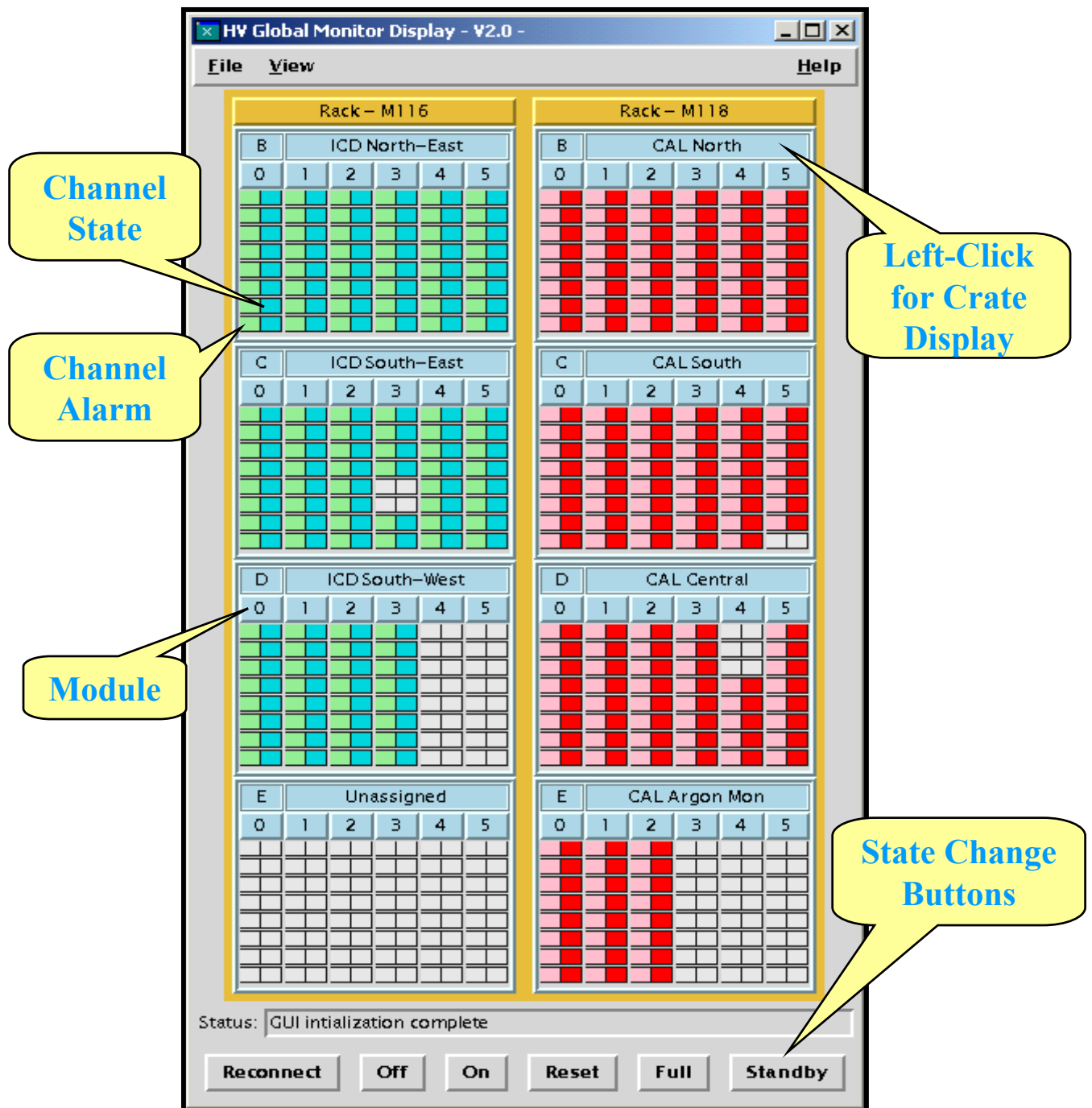
- ◆ Organized by detector page
- ◆ Read-only access
- ◆ Background color indicates alarm state

- **Implementation**

- ◆ Python script
- ◆ Program name - HvuGui.py
- ◆ Configuration scripts - xxx.hvu



Global HV Display



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Global HV Display

- **Purpose**

- ◆ Monitor state of channels in multiple crates
- ◆ Execute multiple-crate actions
- ◆ Initiate crate display

- **Properties**

- ◆ Organized by crate
- ◆ Multi-crate action buttons

- **Implementation**

- ◆ Python script
- ◆ Program name - HvgGui.py
- ◆ Configuration script - xxx.hvg



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Global HV Display

- **Crate button**
 - ◆ Start individual crate display
- **Action buttons**
 - ◆ OFF - set channels to OFF state
 - ◆ ON - set channels to ON state
 - ◆ RESET - reset tripped channels
 - ◆ FULL - set to a full (operational) voltage
 - ◆ STANDBY – set to standby voltage



Global HV Display

- Buttons for other target voltages may be added in the configuration file
- Channel state colors
 - ◆ Purple - OFFLINE, DISABLED
 - ◆ Blue - OFF
 - ◆ Orange – ON, PAUSED
 - ◆ Yellow - AVERAGE, RAMP
 - ◆ Green – HOLDING
 - ◆ Turquoise – LOCKED
 - ◆ Red - TRIPPED



HV Channel Display

Size Control

Page Cycle Control

Right-Click For Limits

Limits

Channel	V_Trip	I_Max	V_Max	V_Set	V_Read	I_Read	State
SA01	-1969	2500	-1680	-1680.0	-1679.6	1702.2	Holding
SA02	-1969	2500	-1680	-1680.0	-1679.4	1707.4	Holding
SA03	-1968	2500	-1680	-1680.0	-1677.7	1700.7	Holding
SA04	-1968	2500	-1680	-1680.0	-1678.7	1699.6	Holding
SA05	-1968	2500	-1680	-1680.0	-1679.3	1702.4	Holding
SA06	-1968	2500	-1680	-1680.0	-1680.4	1699.5	Holding
SA07	-1963	2500	-1630	-1630.0	-1629.5	1654.3	Holding
SA08	-1964	2500	-1680	-1680.0	-1679.9	1702.2	Holding
SA09	-1971	2500	-1680	-1680.0	-1679.3	1704.9	Holding
SA10	-1971	2500	-1730	-1730.0	-1728.4	1750.6	Holding
SA11	-1972	2500	-1630	-1630.0	-1629.4	1652.4	Holding
SA12	-1974	2500	-1730	-1730.0	-1729.4	1749.8	Holding
SA13	-1969	2500	-1680	-1680.0	-1680.7	1701.7	Holding
SA14	-1969	2500	-1630	-1630.0	-1627.7	1705.0	Holding
SA15	-1971	2500	-1630	-1630.0	-1627.7	1751.4	Holding
SA16	-1971	2500	-1680	-1680.0	-1679.3	1703.0	Holding
SA17	-1968	2500	-1730	-1730.0	-1729.0	1753.4	Holding
SA18	-1968	2500	-1630	-1630.0	-1628.4	1644.2	Holding
SA19	-1968	2500	-1730	-1730.0	-1728.9	1740.9	Holding
SA20	-1966	2500	-1730	-1730.0	-1729.5	1751.2	Holding
SA21	-1970	2500	-1590	-1590.0	-1589.8	1606.6	Holding
SA22	-1970	2500	-1550	-1550.0	-1549.1	1568.8	Holding
SA23	-1970	2500	-1630	-1630.0	-1629.8	1652.3	Holding
SA24	-1970	2500	-1680	-1680.0	-1678.3	1701.9	Holding
SA25	-1976	2500	-1590	-1590.0	-1589.1	1509.6	Holding

Status: GUI initialization complete

Reconnect Offline Online Off On Ramp Pause Resume Lock Unlock Reset



HV Channel Display

Standby Entry

Paging Tabs

State Change Buttons

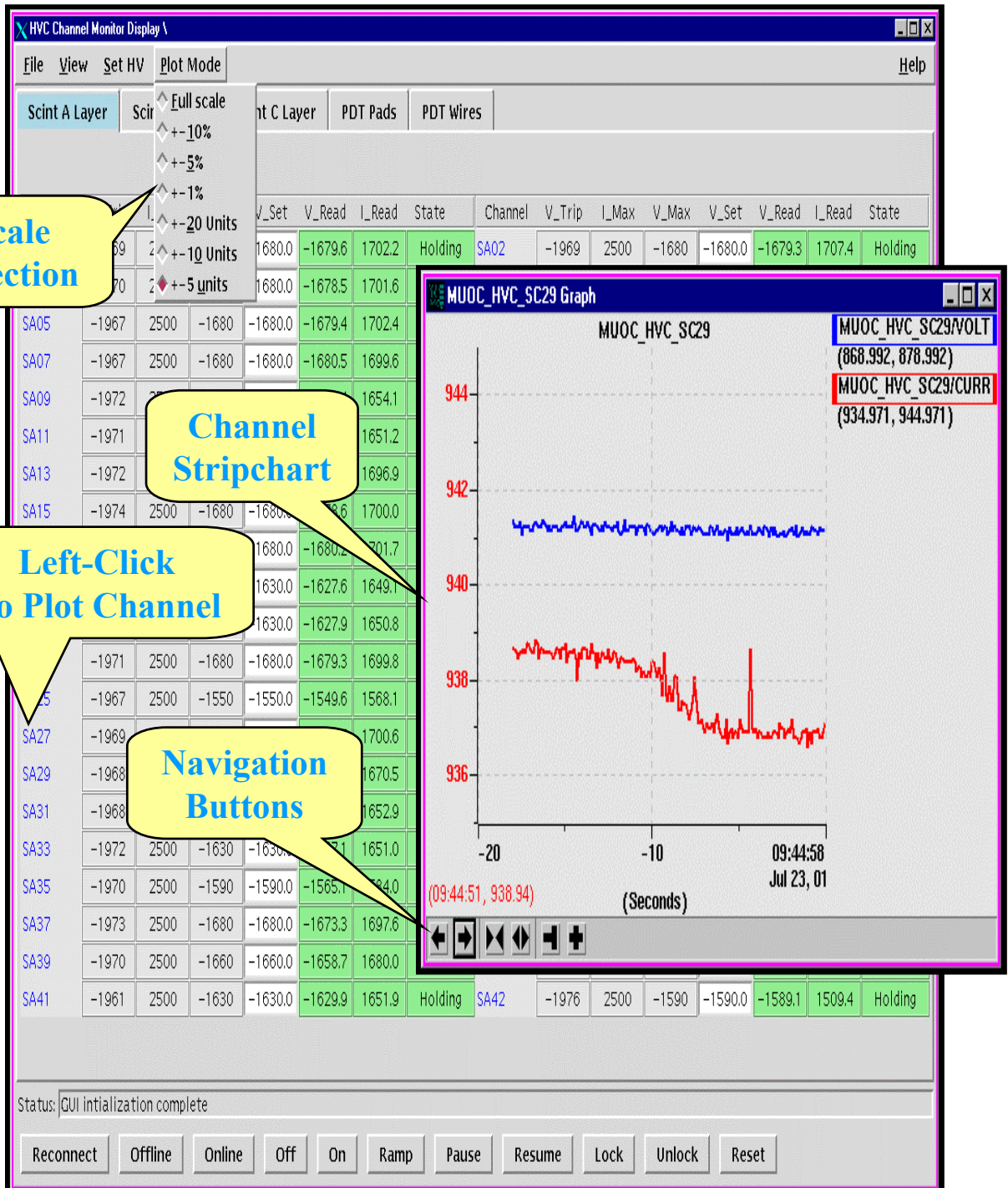
Channel	V_Max	V_Set	V_Read	I_Read	State	Channel	V_Trip	I_Max	I_Read	State	
SA01	-1680.0	-1680.0	-1680.3	1702.3	Holding	SA02	-1969	2500	1707.7	Holding	
SA03	-1680.0	-1680.0	-1680.3	1701.7	Holding	SA04	-1968	2500	-1677.7	1700.7	Holding
SA05	-1680.0	-1680.0	-1680.3	1702.4	Holding	SA06	-1968	2500	-1678.8	1699.6	Holding
SA07	-1680.0	-1680.0	-1680.3	1699.4	Holding	SA08	-1964	2500	-1679.9	1702.1	Holding
SA09	-1680.0	-1680.0	-1680.3	1654.1	Holding	SA10	-1971	2500	-1679.1	1704.7	Holding
SA11	-1680.0	-1680.0	-1680.3	1651.1	Holding	SA12	-1973	2500	-1728.3	1750.6	Holding
SA13	-1680.0	-1680.0	-1680.3	1696.9	Holding	SA14	-1974	2500	-1629.5	1652.5	Holding
SA15	-1680.0	-1680.0	-1680.3	1699.9	Holding	SA16	-1970	2500	-1729.4	1750.1	Holding
SA17	-1680.0	-1680.0	-1680.3	1701.8	Holding	SA18	-1971	2500	-1680.7	1701.4	Holding
SA19	-1680.0	-1680.0	-1680.3	1648.9	Holding	SA20	-1970	2500	-1679.9	1704.8	Holding
SA21	-1680.0	-1680.0	-1680.3	1650.8	Holding	SA22	-1968	2500	-1728.9	1751.4	Holding
SA23	-1680.0	-1680.0	-1680.3	1699.8	Holding	SA24	-1967	2500	-1680.9	1702.8	Holding
SA25	-1680.0	-1680.0	-1680.3	1568.0	Holding	SA26	-1968	2500	-1729.1	1753.8	Holding
SA27	-1680.0	-1680.0	-1680.3	1700.7	Holding	SA28	-1968	2500	-1628.3	1644.1	Holding
SA29	-1680.0	-1680.0	-1680.3	1670.8	Holding	SA30	-1966	2500	-1728.9	1741.0	Holding
SA31	-1680.0	-1680.0	-1680.3	1653.0	Holding	SA32	-1966	2500	-1729.3	1750.9	Holding
SA33	-1680.0	-1680.0	-1680.3	1651.2	Holding	SA34	-1969	2500	-1589.5	1606.7	Holding
SA35	-1680.0	-1680.0	-1680.3	1584.0	Holding	SA36	-1970	2500	-1548.9	1568.5	Holding
SA37	-1680.0	-1680.0	-1680.3	1696.5	Holding				-1629.8	1652.2	Holding
SA39	-1680.0	-1680.0	-1680.3	1680.0	Holding				-1678.2	1701.8	Holding
SA41	-1680.0	-1680.0	-1680.3	1651.8	Holding				-1589.1	1509.6	Holding

Status: GUI initialization complete

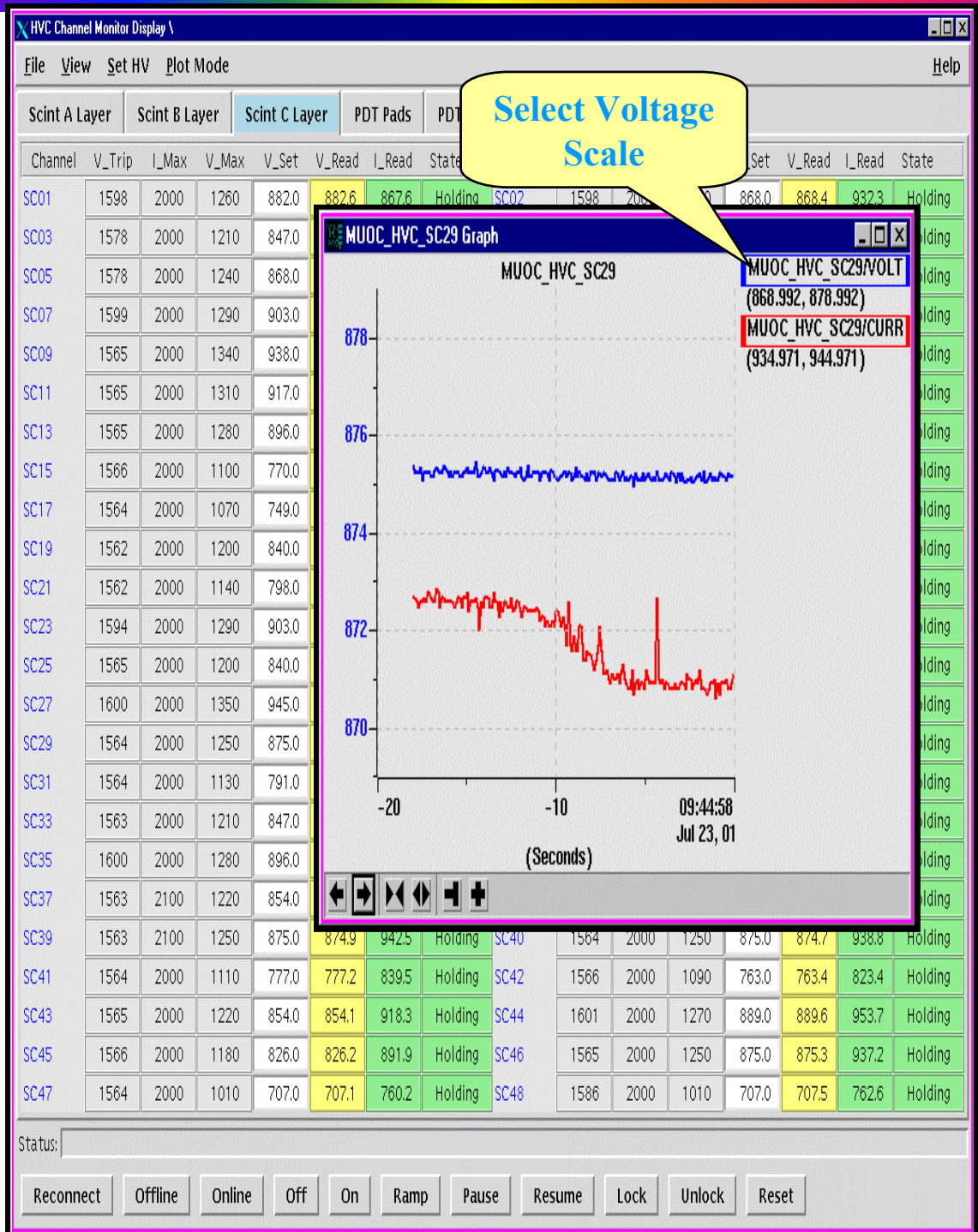
Reconnect Offline Online Off On Ramp Pause Resume Lock Unlock Reset



HV – Channel Display



HV Channel Display



HV Channel Display



HV Channel Display

- **Purpose**

- ◆ **Monitor individual channels**
 - **State**
 - **Voltage and current readback**
 - **Target voltage**
 - **Voltage and current trip levels**
- ◆ **Execute all-channel and individual channel actions**
- ◆ **Set all-channel and individual channel target voltages**
- ◆ **Usually displays a single crate**



HV Channel Display

- **Properties**

- ◆ Organized by channel
- ◆ Multi-channel action buttons
- ◆ Channel action menu button

- **Implementation**

- ◆ Python script
- ◆ Program name - HvcGui.py
- ◆ Configuration script - xxx.hvc

- **Action buttons**

- ◆ Similar to global display +
 - OFFLINE/ONLINE
 - PAUSE/RESUME
 - LOCK/UNLOCK

- **Channel state colors**

- ◆ Same as Detector display



Diagnostic Guidelines

- **Channel is in offline state**
 - ◆ Missing HV module
 - ◆ Incorrect module type in database
 - ◆ Faulty module
- **Module trips after transition from off to on state**
 - ◆ After a period with the power off, the channel may not be stable. Leave the power on for ~1/4 hour, after which the channel may recover.
 - ◆ Faulty module



Diagnostic Guidelines

- **Module trips during ramp but has not exceeded either the voltage or current trip limit**
 - ◆ After a period in the off state, the channel may not be stable. Leave the channel in the on state at zero output for ~1/4 hour, after which the channel may recover
 - ◆ Faulty module



Diagnostic Guidelines

- Ramp away from zero volts does not converge to target voltage
 - ◆ Record tuning parameters set incorrectly
 - ◆ Faulty module
- Current trip during ramp caused by capacitance charging
 - ◆ Reduce ramp rate
 - ◆ Increase current scaling factor parameter
 - ◆ Lengthen parabolic ramp region



Diagnostic Guidelines

- Ramp toward zero volts does converges to the target voltage very slowly
 - ◆ Reduce load capacitance or increase shunt resistance
 - The Cockcroft-Walton generator is a charge pump and can only drive the voltage away from zero (positive or negative). Ramping toward zero requires a shunt resistance to discharge the load capacitance and the voltage divider resistance in the pod is ~10-50 Megohms.

